A Web-based GIS Application With a Focus on Source Water Protection Goals of the Safe Drinking Water Act

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Abstract

The U.S. Environmental Protection Agency (EPA) Office of Ground Water and Drinking Water is developing a web-based geographic information systems (GIS) application related to major Safe Drinking Water Act programs. The Agency's goals include identifying contaminant risks for drinking water intakes and documenting how states are setting up source water protection areas. States delineate source water protection areas to protect public water supply intakes for surface water, wellhead protection areas for ground water, and for conjunctive situations where there are geohydrologic interactions between surface and ground water sources. The protection areas are created to document risks from contaminants and to provide a measure of susceptibility to contaminant sources. Contaminant risks can include such sources as Underground Injection Control wells or contaminants such as methyl tertiary-butyl ether leaking from Underground Storage Tanks. A GIS prototype application is described that combines the Environmental Systems Research Institute's ArcIMS mapserver with dataservers hosting attributes from a range of major EPA data systems such as the Safe Drinking Water Information System and information emerging from state source water protection initiatives. Proximity analysis techniques are highlighted illustrating ways that the application provides desktop GIS functionality accessible through web browsers.

Background and Purpose

The U.S. Environmental Protection Agency's (EPA's) Office of Ground Water and Drinking Water (OGWDW) is applying state-of-the-art, web-based mapping and database technology to enhance Agency capabilities to identify major contaminant risks to public drinking water supplies. The focus is on those environmental threats related to provisions in the 1996 Safe Drinking Water Act (SDWA) amendments requiring states to develop source water assessment and protection (SWAP) programs. OGWDW aims to identify core information components in these state SWAP programs and to evaluate technical approaches to compile these core state mapping and database products using consistent national formats.

In addition to defining efficient ways to take advantage of final state SWAP materials that will become available beginning in early spring 2003, EPA is working to enhance the value of information from other SDWA programs as components in geospatial applications. Improvements in integrated mapping and data query functionality are being pursued for the OGWDW programs (and related data systems) listed in Table 1.

The OGWDW also promotes the use by states of the state version of the Safe Drinking Water Information System (SDWIS/State). Summary information form SDWIS/State or other state datasystems is compiled in the federal system, known as SDWIS/Fed. The new OGWDW geospatial application will develop a variety of tools to assist in the presentation and mapping of information in SDWIS/Fed. Relevant SDWIS data include information on the occurrence of detections or violation of SDWA standards (e.g., Maximum Contaminant Level [MCL] criteria for chemicals such as benzene and standards for physical indicators such as turbidity). SDWIS/Fed can also provide information on the population served by a facility and on the local administrative units (e.g., counties) associated with a water supplier. The OGWDW is working to develop geographic information systems (GIS) data layers to map the locations of surface drinking water intakes using the U.S. Geological Survey (USGS) National Hydrography Dataset (NHD). These locations are then placed in a special EPA geodatabase called the Reach Address Database (RAD), which provides a common infrastructure for use in the OGWDW's web-based application. The RAD also provides a standard source for a variety of other useful GIS layers and datasets drawn from a range of EPA programs (e.g., Clean Water Act Section 303(d) Total Maximum Daily Loads [TMDLs]) as well as helpful navigation layers such as county boundaries, watershed polygons, or major roads. Much of this information is publicly accessible through the Office of Water's (OW's) EnviroMapper (Internet address: http://www.epa.gov/waters/).

The OGWDW application also seeks to make effective use of information in the EPA data warehouse system known as Envirofacts (Internet address: http://www.epa.gov/enviro/index_java.html). Envirofacts is a gateway to several EnviroMapper-style applications (e.g, the EnviroMapper for Superfund). It also provides sets of web-based forms where users can provide inputs to generate a variety of custom data table displays. The OGWDW has developed several data table query tools in Envirofacts to help show the occurrence of contaminants related to existing drinking water regulations or contaminants under consideration for criteria review or the development of new regulations. These tools (e.g, the National Contaminant Occurrence Database or NCOD) aim to tap good quality monitoring data gathered by the EPA, other federal agencies (especially the USGS), and state and local governments (Internet address: http://www.epa.gov/enviro/html/icr/index.html). Where new data collections are targeted to steer the development of new drinking water criteria for chemical or microbial contaminants, special information collection rule (ICR) datasets are assembled, several of which are now publicly available (Internet address: http://www.epa.gov/enviro/html/icr/index.html).

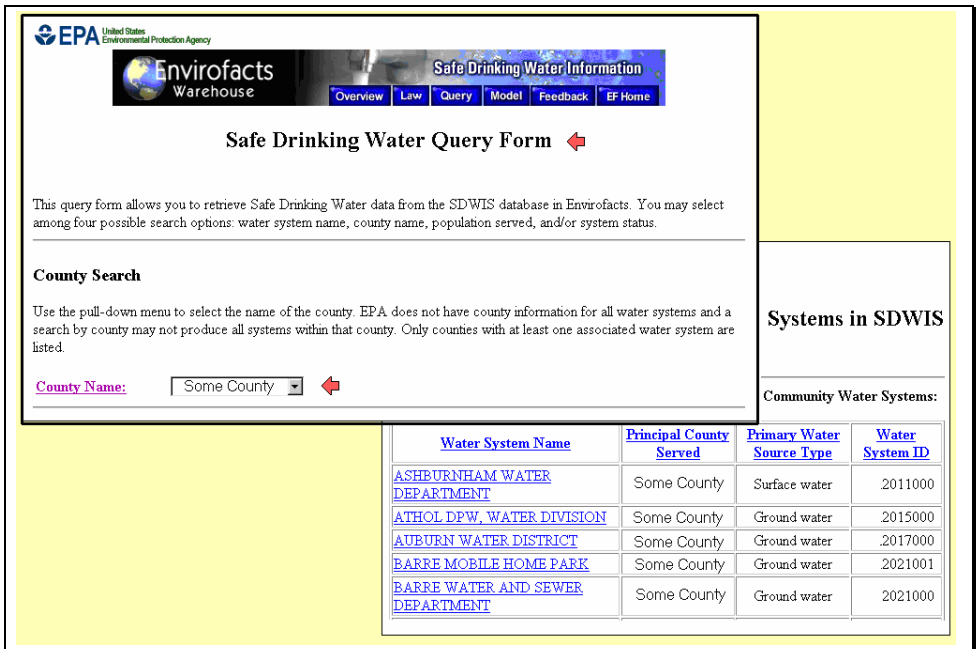
Table 1: SDWA Programs Relevant to OGWDW's Web-based Geospatial Application	
OGWDW Program	Major Program Themes Relevant to Geospatial Application
Underground Injection Control (UIC) Program	Focus on Class I and Class V wells. EPA's Toxics Release Inventory tracks many wastes disposed of in UIC Class I wells. Releases from the drains and cesspools associated with Class V wells are usually major management concerns in state SWAP programs.
Wellhead Protection Program (WHPP)	The national WHP Program was established in 1986 by the Safe Drinking Water Act. WHPPs are the foundation for the ground water components in many of the state Source Water Assessment Programs required under the 1996 SDWA amendments.
Sole Source Aquifers (SSA)	Sole Source Aquifer designations protect an area's ground water resource by requiring EPA review of any proposed projects within the designated area that are receiving federal financial assistance.
Public Water Supply System Program	Implementation of SDWA rules and standards, analysis of contaminant occurrence in public water supplies, and oversight for communication of information to the public through such vehicles as Consumer Confidence Reports (CCRs).
Tribal Programs	Tribal groups often manage their own drinking water facilities, and many are developing their own WHP and SWAP programs.
Environmental Justice	OGWDW takes steps to identify the impacts of its programs on small or disadvantaged communities and to coordinate with other EPA initiatives addressing Environmental Justice (EJ) concerns.

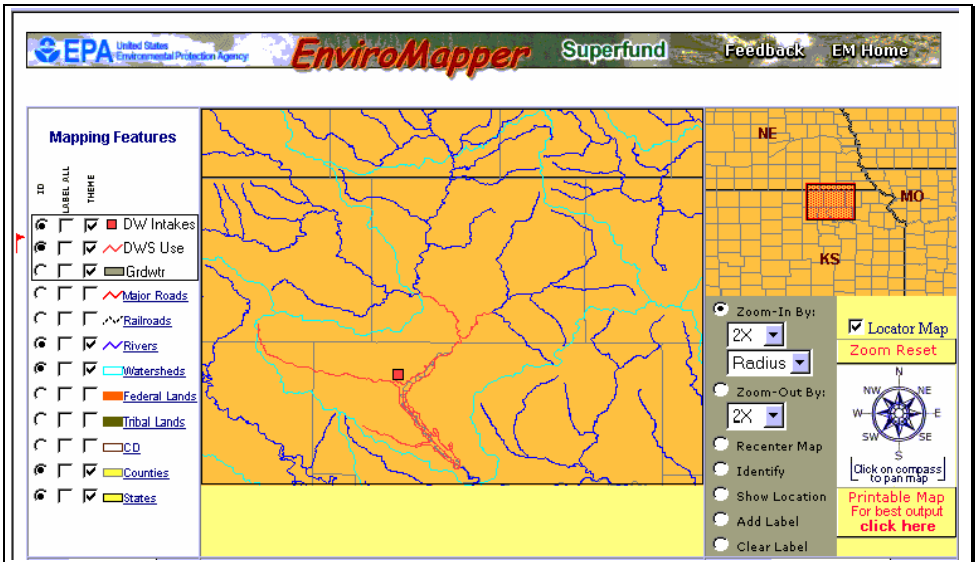
Clearly a wealth of available database and GIS materials are available. The aim of the web-based drinking water geospatial application is not to create new content. The goal is to help identify high-priority content and feature capabilities to focus the design of the application in order to ensure that major business needs of OGWDW programs are addressed. Achieving these objectives involves appropriate surveys of EPA staff to identify user needs and requirements. These survey results then guide the technical implementation work leading to the final web-based product.

Defining High-Priority-User Requirements

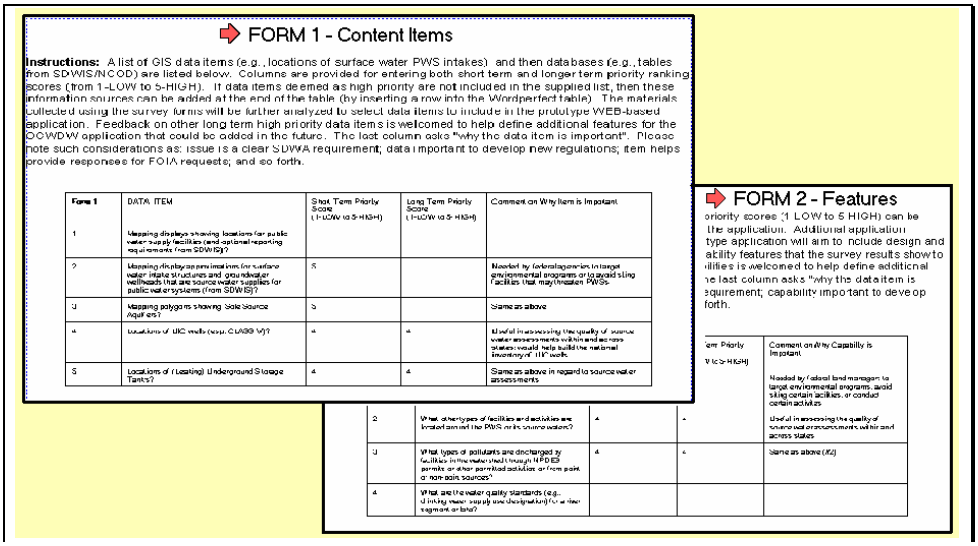
When developing any new data system or application, EPA ordinarily conducts a requirements identification process. Where regulatory provisions are at issue, or where the new system involves substantial start-up costs with ongoing maintenance needs over a period of years, the requirements definition stage can become very elaborate and, by itself, can take months or years to complete. The OGWDW drinking water application effort was able to adopt a substantially streamlined approach to the user requirements identification process. This was possible because the initial target audience were staff working with programs in the headquarters, branches, and divisions of the OGWDW. The application was envisioned as a secure, passworded facility. The application would make the fullest possible use of existing EPA and other federal agency Internet-accessible data systems. Draft content from state SWAP programs would be incorporated, but once again, the application would build on work already accomplished by EPA's state partners. The aim was to define what content items (GIS layers and databases) and what application performance features were needed to address major EPA staff needs.

There was also a clear interest that as the technical design of the application was implemented, it should aim to synthesize the strengths of data query applications in Envirofacts with the ability of EnviroMapper-type tools to present maps where users could interactively turn features off and on, zoom in or out, and identify specific attributes in the map display. Typical features of such data-query-only and map-only applications are illustrated in Figures 1 and 2.





Focus group techniques were used to document high-priority-user requirements from OGWDW staff. During the initial phase of application development, inputs were obtained from members of OGWDW's Drinking Water Protection Division. During 2002, user priorities have been re-evaluated within this division, and the survey process has been expanded to the OGWDW Standards and Risk Management Division. The aim is to document the high-priority-application needs for all the branches in both divisions of OGWDW.



FORM 1 - Content Items

Instructions: A list of GIS data items (e.g., locations of surface water PWS intakes) and then databases (e.g., tables from SDWIS/NCOD) are listed below. Columns are provided for entering both short term and longer term priority ranking scores (from 1-LOW to 5-HIGH). If data items deemed as high priority are not included in the supplied list, then these information sources can be added at the end of the table (by inserting a row into the Wordperfect table). The materials collected using the survey forms will be further analyzed to select data items to include in the prototype WEB-based application. Feedback on other long term high priority data items is welcomed to help define additional features for the OGWDW application that could be added in the future. The last column asks "why the data item is important". Please note such considerations as: issue is a clear SDWA requirement; data important to develop new regulations; item helps provide responsee for FOIA requests; and so forth.

Form 1	DATA ITEM	Short Term Priority Score (1-LOW to 5-HIGH)	Long Term Priority Score (1-LOW to 5-HIGH)	Comment on Why Item is Important
1	Mapping displays showing locations for public water supply facilities (and optional reporting requirements from SDWIS)?			
2	Mapping display as previous item for surface water intake structures and groundwater wellheads that are source water supplies for public water systems (from SDWIS)?	5		Needed by federal agencies in target environmental programs or to avoid siting facilities that may threaten PWSs
3	Mapping polygons showing Sole Source Aquifers?	5		Same as above
4	Locations of UIC wells (esp. CLASS V)?	4	4	Useful in assessing the quality of source water assessments within and across states; would help build the national inventory of "II" wells
5	Locations of (Leaking) Underground Storage Tanks?	4	4	Same as above in regard to source water assessments

FORM 2 - Features

priority scores (1 LOW to 5 HIGH) can be the application. Additional application type application will aim to include design and ability features that the survey results show to ilities is welcomed to help define additional he last column asks "why the data item is equirement; capability important to develop forth.

erm Priority 1 to 5=HIGH)	Comment on Why Capability is Important
	Needed by federal land managers to target environmental programs, avoid siting certain facilities, or conduct certain activities
	Useful in assessing the quality of source water assessments within and across states
	Same as above (#2)

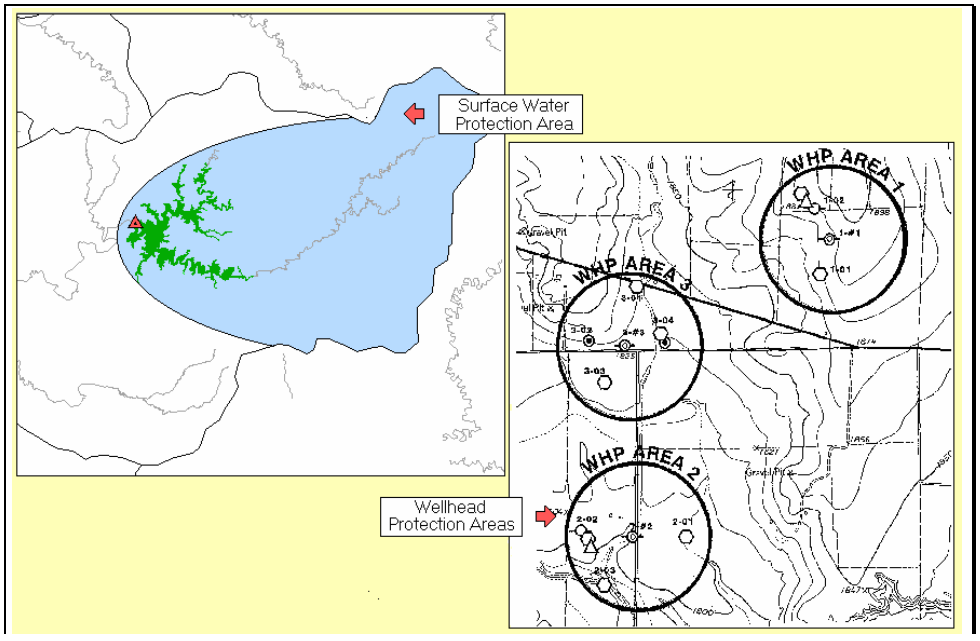
2	What other types of facilities and activities are located around the PWS or its source water?	4	4	
3	What types of pollutants are discharged by facilities in the watershed through NPDES permits or other permitted activities or from point or non-point sources?	4	4	Same as above (#2)
4	What are the water quality standards (e.g., drinking water supply use designation) for water segment or lake?			

The surveys aimed to record staff priorities using a form related to major database and GIS coverage content items and a companion form to indicate desirable performance features. For high-priority-application features, the survey results were examined to check for implicit content item needs. For instance, if there was consensus that the application should map certain types of information selected for a specified county within a state, then an implicit GIS content item would be a standard polygon layer of county boundaries. Figure 3 shows the general layout of the two survey forms.

To assist in making final determinations of the most important content and feature capabilities, staff were requested to enter short comments to identify situations where the application characteristic was clearly related to major Agency responsibilities defined in laws, regulations, or similar strategic requirements. This information can be very helpful as a tie-breaking tool. In the design of a geospatial framework, the use of this two-form approach proved very effective in capturing major end-user needs, thereby combining both conventional table-oriented database queries with GIS mapping capabilities.

Initial Implementation of the Web-based Application

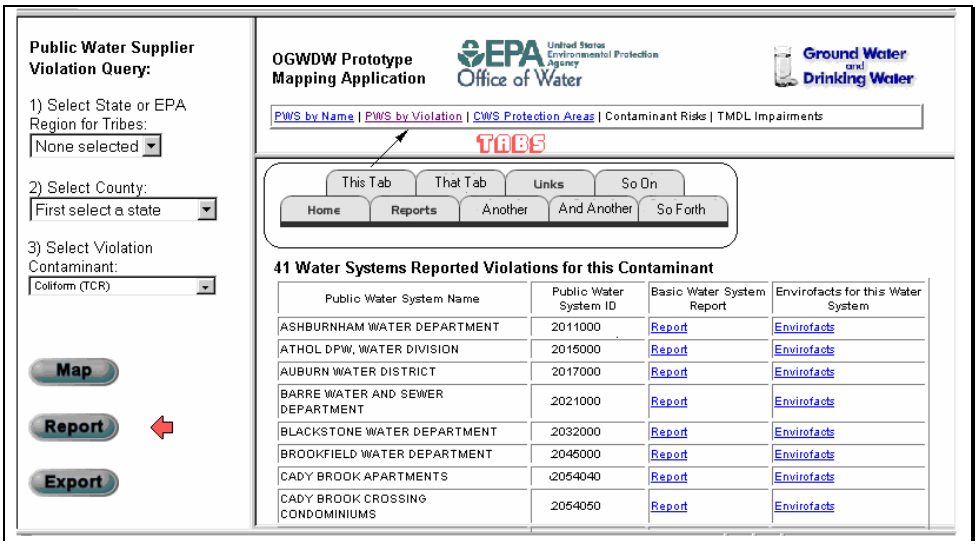
During 2001, the OGWDW drinking water application was implemented on a prototype basis. The prototype was based on an Oracle 8*i* database server, with tabular web pages generated using the Oracle Application Server (OAS). GIS functions and rendering of graphic map images were accomplished with version 3.1 of the Environmental Systems Research Institute (ESRI) ArcIMS mapserver. At that time, most of EPA's mapper applications were still based on the older ESRI MapObjects mapserver. The OGWDW wanted to take advantage of ESRI's latest mapserver systems. Valuable insights came from examination of a prototype version of a new EPA mapper application called Window To My Environment (WME), which took advantage of the initial version 3.0 release of ArcIMS (Internet address: http://www.epa.gov/enviro/wme/). The OGWDW initiatives were, in a very real sense, pioneering efforts that have yielded a number of insights on efficient user-interface design. These insights have been shared with OW's

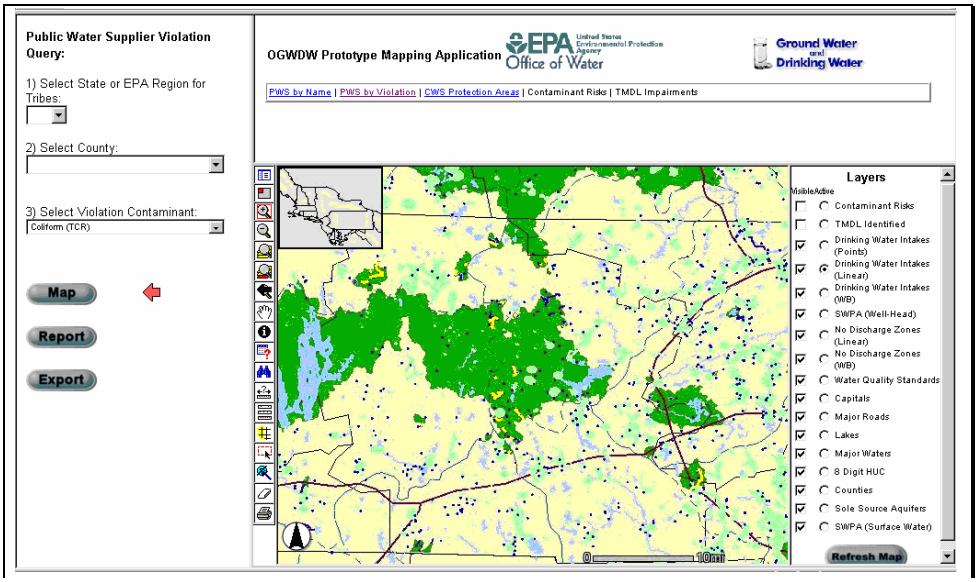


geospatial community as other programs take steps to convert their applications to the new ESRI ArcIMS standard.

The primary focus for the OGWDW application is to organize information in proximity to drinking water supply intakes (and wellheads for ground water). State source water assessments aim to delineate protection areas around these intakes where management initiatives will be pursued to reduce risks from identified contaminants. Figure 4 shows idealized representations of protection area patterns that states may select to protect surface water or ground water sources for public drinking water supplies. The OGWDW application contains a variety of GIS data layers and connects to databases designed to document the contaminants, potential contaminant sources, and other information to help define the vulnerability of the drinking water resources. For surface source waters, the application aims to facilitate the analysis of information related to permitted municipal and industrial discharges or nonpoint source concerns such as confined animal feeding operations, where contaminants could be released posing risks to downstream surface water intakes. For wellheads, the OGWDW application captures information on vulnerability from standard USGS coverages for principal aquifers, surficial geology, and areas with karst topography. Combined with information from other USGS data systems, and materials provided from state WHP programs, tables and vicinity maps can be easily generated related to management strategies for reducing major ground water contaminant risks.

The application's user interface is constructed with the assumption that EPA staff will generally want to perform a query against one or more databases to generate a tabular report. The application then takes information from this custom query to produce a GIS vicinity map based on key information attributes from the report. Several types of reports are required to serve the needs of the different programs within the OGWDW. A set of tabs in a special-use interface window allows the selection of different query forms. Figure 5 illustrates the integration of the tabs and query forms used to generate a tabular report. Figure 6 shows a GIS vicinity map based on information generated from a query. For security reasons, these displays have been edited to suppress the state and county inputs used in the report and GIS map.





The types of questions summarized in Table 2 received attention in work on the initial prototype application for the development of tabs, query forms, and associated GIS maps. In addition to the functionality controlled through the tabs, the map window in the application provides the features found in the current EPA mapper applications. Starting from any map display, users can turn data layers on or off; can zoom in or zoom out; and, through a set of built-in ESRI tools, can display information tables about a particular data layer or perform additional analysis operations based on the boundaries of GIS themes and associated information attributes. For instance, a buffer tool can be applied to select contaminant hazards (e.g., locations of UIC Class V wells) within a certain distance of a drinking water intake. The contaminant hazards selected through this sort of proximity analysis can be compared with the boundaries of state-defined protection areas. This provides a spatial sensitivity analysis tool to facilitate review of state SWAP

materials.

Current Enhancement Efforts and Future Directions

The initial prototype work during 2001 focused on states in the Northeastern United States. The Northeast was chosen primarily to take advantage of source water assessment materials from states in this area and data products developed cooperatively by EPA and the USGS to provide georeferencing for community water system surface water intakes based on the NHD and OW's Enviromapper project. During 2002, additional states will be added to the application from the Midwest (e.g., Missouri and Ohio) and the Pacific Northwest (e.g., Washington). A number of "national" GIS data layers (and associated databases) will be included as well as "draft" materials, mainly items related to state source water protection programs, where final products will likely not be available until the end of calendar year 2003. In the aftermath of "911," work on the OGWDW application has heightened attention to security issues. Several aspects of the application (e.g., precise locations of drinking water intakes) require very stringent security. As a result, the application will operate using special EPA Intranet facilities in the foreseeable future.

Table 2: Report and Mapping Functions Considered in Implementation of Prototype Application	
Query Description	Characteristics of Map Display
Background information on a public water system serving a particular county (from SDWIS/Fed, Consumer Confidence Reports, or available Source Water Assessment summaries).	Vicinity map for selected county showing intakes (wellheads) associated with a particular water system.
For a specific county, show table of public water supplies with recent MCL or other SDWA standards violations (using data from SDWIS/Fed).	Vicinity map highlighting water systems with exceedances of contaminant standards.
Select protection areas within a county where a state has documented risks from specific contaminants or potential contaminant sources.	Vicinity map highlighting protection areas and associated water system intakes where contaminant risks are documented.
Select surface waters within a county where there are Clean Water Act TMDL listings for specific pollutants.	Vicinity map highlighting TMDL waters, with overlays including protection areas and intakes in proximity to the TMDL-listed waters.

For standard national GIS coverages and databases, the application will make maximum possible use of established EPA infrastructure tools. The basic design structure for the prototype will follow the business rules in the EPA RAD geodatabase system (Plastino, 2001). EPA's RAD is also the preferred source for accessing several specific data systems (e.g., for TMDLS and Clean Water Act Water Quality Standards) and for a range of convenient "navigation" polygons (e.g., state and county boundaries or the full set of surface hydrography features in NHD). EPA's Envirofacts data warehouse system will also be used to the maximum degree possible to access data from such major EPA databases as the Permit Compliance System (PCS), OW's legacy STORET water quality monitoring database, and the NCOD and ICR data systems established in Envirofacts by the OGWDW. To the extent possible, major USGS datasets such as the National Water Information System (NWIS) will be tapped directly. Using established framework systems ensures the reliability of the information and eliminates the often significant maintenance expenses involved in storing and updating major federal agency data systems. The OGWDW application is primarily a set of targeted geospatial query, analysis, and presentation tools rather than an independent data repository.

For many state-derived datasets, the materials will either be used in the prototype as draft documents until such time that more refined materials are available or until EPA defines the specifications to make the state materials part of a nationally consistent framework. For such datasets, which include such items as state-delineated source water protection area polygons, the application will serve as an interim data custodian. All technical design information for such special GIS and database items will be documented and shared with the OW geospatial team. As data standards and business rules emerge, these special state materials can be progressively shifted to EPA's major infrastructure systems (e.g., the RAD and Envirofacts).

During 2002, the OGWDW application will see major enhancements related to the data and presentation challenges related to working with both surface water and ground water systems. For the wellheads and wellhead protection areas that figure into state source water assessments, prototype work will be undertaken to document the geohydrological settings for the ground water resources and other pertinent information (e.g., depth of wells and the methodologies applied in delineating wellhead protection areas). For each wellhead in a set of select states, the types of information tracked for state and national reporting purposes in EPA's Wellhead Protection Program Biennial Report (e.g., EPA 1997) will be coded at the wellhead level. This high-resolution information will help sharpen federal and state abilities to target high-priority management issues and to seek needed conjunctive approaches where surface water and ground water contamination issues are significantly correlated.

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